Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 131 (2015) 701 – 710
Procedia Engineering
www.elsevier.com/locate/procedia

World Conference: TRIZ FUTURE, TF 2011-2014

A proposal of a systematic and consistent Substance-Field Analysis

Alexis Bultey [a,b], Wei Yan[a,c] Cécillia Zanni[c]

[a]LGeCO, 24 Boulevard de la Victoire, 67084 Strasbourg Cede, France
[b]ECAM Strasbourg-Europe, 2 rue de Madrid, 67300 Schiltigheim, France
[c]ICUBE(BFO team), 300 bd Sébastien Brant BP 10413 F-67412 Illkirch Cedex, France

Abstract

This paper presents a simplification of one of the TRIZ methods, the Substance-Field Analysis (SFA). Applying TRIZ methods is often time consuming and therefore a barrier to its application in the industry. Our research group strives to simplify TRIZ methods to make their use more widespread. This SFA simplification was obtained during the implementation of a computer aided SFA. This implementation implies an ontological phase, which leads to the translation of the SFA terminological and conditional knowledge in a computer language. In addition to their operational interest, the chosen computer languages (Description Logics and First Order Logic) have formal interest for the SFA. The complexity of the application of SFA has regularly been reported by the TRIZ community. The SFA terminology suffers from a lack of normalization and the 76 Standards deployment is an empirical process. We propose a clarification of the Substance-Field Modeling terminology and a systematic process for deploying the 76 Standards. Thanks to Description Logics, the SFA terminology is formalized in an automatically consistency checked model and First Order Logic ensures the systematization of the 76 Standards deployment.

Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC

Keywords: TRIZ, substance-field analysis, ontology, description logics, first order logic;

1. Introduction

The scientific objective of this work is rooted in a larger project initiated by our laboratory. This project aims to obtain models of innovative design [1][2][3]. The primary objective of this project is to formalize the TRIZ knowledge. As it was discussed in [4][5], formalization appears to be a necessary step in the progression of TRIZ. We believe it will allow a better understanding of TRIZ and an easier dissemination in industrial circles. We use an ontological approach to shape this model. Ontologies have the double advantage of formalizing knowledge and being easily implemented in a knowledge based-system. In this work, we limit our knowledge base to one of TRIZ methodologies. Our choice is the Substance-Field Analysis (SFA). The reasons for this choice are related to three considerations about SFA: its methodological strengths, its lack of formalism and its partial integration into existing

Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC
doi:10.1016/j.proeng.2015.12.357

software solutions. In this paper, we focus on our formalization work and our formal ontological result. To achieve this formal modeling of the SFA, we use the formalism of Description Logics (DL) [6] for definitional knowledge (the SFA terminology) and the Fist Order Logic (FOL) formalism for conditional knowledge (the 76 Inventive Standards application). DL is one of the most expressive representation languages. DL enables to reproduce consistently SFA definitions without compromising on their interpretation. As FOL, DL benefit from a formal framework derived from predicate logic and set theory, considered today as the pillars of scientific formalization.

The general plan of the paper is as follows. Section 2 starts by underlining the problem of the SFA formalism. Section 3 describes our ontological approach to formalize SFA. Section 4 shows the contributions through a summary of SFA terminology and some flow charts which synthetize a proposal of systematic SFA.

Nomenclature

SFM	Substance Field Model
DL	Description Logics
SFA	Substance Field Analysis
FOL	First Order Logic

2. SFA formalism issues

In addition to translation problems reported in [4] and in [5], SFA suffers from a lack of terms normalization. Those lacks were highlighted by [7], [8], [9], [10]. Normalization problems are rooted in the definition of the SFM elements like substance or field. The ‘substance’ term is, for example, used interchangeably to represent either physical objects, systems or materials in [11]. The ‘field’ term is not actually defined by its intension (set of formal attributes) but by its extension (set of formal objects: mechanical field, magnetic field ...). Moreover, the ‘field’ sets change from source to source [11] [7] [12].

The 76 Inventive Standards proposed by Altshuller have been criticized due to their inhomogeneity, redundancy, unsort and difficult implementation [7] [9]. We give a non-exhaustive list of these problems:

- Standards classes 1, 2 and 3 are related to technical systems in general (class 1 is about their composition and decomposition, class 2 deals with their evolution and class 3 corresponds to their transition to super-systems or to micro-level). Conversely, class 4 is related to a particular kind of technical systems, the measurement systems, and class 5 is a guide for applying standards and therefore works at a meta-level.
- The sub-class 1.1 entitled the SFM synthesis includes standards (Standards 1.1.2 & 1.1.3) that have no link with the construction of a Complete SFM.
- The standard 1.2.5 is not written at the same description level than the precedent standards from the sub-class 1.2, it’s a specification of some more general standards.
- Too much attention is paid to some particular SFM; the magnetic SFM is present not only in the sub-class 2.4 but also in standards of other classes.

The formulation of standards is very different across classes and sub-classes to which they belong. The selection of standards is not very intuitive and often leads to browse the entire list.

An ontological approach has been selected to formalize the SFA, the operational goal of this ontological approach is to obtain a computational model of SFA. To produce an operational ontology of a domain, it is usual to produce first a formal ontology of this domain. We take benefits from this formalization stage to achieve our scientific goal of SFA formalization. In the next section, the ontological methodology used is described.

3. Ontological methodology

Aware that there is no reference framework for ontology construction, we propose a process inspired by [13]. We wish to clarify that the process described here has only an explanatory value. Far from being a sequence of steps the process is in practice an iterative one that involves continual back and forward movements between each step. Our formalization is performed in two steps. The first step is a SFA normalization. This step is carried out using an automatic analysis. The second step is ontologization, it consists in translating the normalization in a formal ontology using DL and FOL syntax.

Automatic analysis, performed using the tool Terminae [14] allowed us to determine the central terms of the SFA. Terminae is a methodology and a tool to build normalization. Normalization allows us to restrict the interpretation possibilities and objectify knowledge. Before reaching this normalization stage, we should introduce the corpus source.

In such an approach, the choice of corpus is often predetermining for the future. But the relevance of the choice is difficult to judge even a posteriori, and no methodology exists for this purpose. Therefore, we stand up for extracting knowledge from various sources that we classify into three categories:

- The first source is called the “mother source”; it includes all the relevant passages of the book "Creativity as an exact science" [11]. Considered by the author as his best book, it is also one of the few books translated into English. This book contains an introduction to SFM modeling, and a first version of the standards.
- The second source qualified as “daughter source” includes selected pieces of the books "TRIZ: The right solution at the right time" [12] and "Engineering of creativity" [7]. These books were recommended by TRIZ Experts as books in continuity of Altshuller’s thought. In [12], an entire chapter is devoted to the SFA and an annex to the latest version of the 76 inventive standards. In [7], a chapter proposes a thesaurus listing resources type, a short chapter about SFM and a substantial chapter about standards deployment.
- The third source said the “cousin source” is one of SFA current view; it is the view of the community gathered around the TRIZ Journal. It collects documents [15] explaining their SFA understanding.

Among the 40 000 words of the corpus, the mother source contains 30%, the daughter source is about 50% and the cousin source is about 20%. The corpus is a specialty corpus not annotated and it was primarily in book form. It has been rewritten in a readable format for computer. Our automatic analysis on the SFA corpus is performed through three phases:

- First, the morphosyntactic labeling: it’s a tagging of the corpus realized with TreeTagger [16]. It enables to annotate text with information (kind of words: nouns, verbs, infinitives and particles).
- Second, the extraction of terminology: Yatea [17] extracts the most used terms in tagged corpus,
- Finally, Terminae enables to choice relevant terms and to fix their definition.

After this normalization step, the ontologization step has been performed via ICOM [18]. ICOM is a conceptual modeling tool, which allows designing graphical ontologies. DL reasoner is used by the tool to verify the specification, infer implicit facts, and manifest any inconsistency. ICOM allows us to detect incoherent term definitions in respect of those previously introduced.

For example, the ‘Internal Complex SFM’ term commonly used in SFA has been modified. ‘Internal Complex SFM’ is traditionally classified as a ‘Complex SFM’. It is defined as a SFM composed of a field and two substances, one of those substances is itself composed of two substances and a field. According to the ICOM DL reasoner which detects logical errors, this definition is inconsistent with the definition of a ‘Complex SFM’ that we introduced before. ICOM actually forbids us to define ‘Internal Complex SFM’ as particular case of ‘Complex SFM’. This subsumption link is inconsistent. ICOM infers that the definition of ‘Internal Complex SFM’ is a specification of ‘Simple SFM’. To correct this anomaly and to avoid common errors, we chose to rename it as a ‘Developed Simple SFM’. Only the name of this SFM changes, it retains its original description.

Another notable change is the ‘Measurement SFM’ term definition. A Measurement SFM is traditionally defined as a combination of two fields and a substance, and it represents a particular technical system. But ICOM prevent us to enter this definition. As a representation of technical system, the Measurement SFM must be a specification of a Complete SFM and it must be composed at least of two substances. We propose a new definition inspired from [19].

We define the Measurement SFM as a Complete SFM with an Instrument Substance. We introduce some new definitions for Instrument Substance and Tool Substance. Both substances achieve the function of a system but one is the target of an action providing by the Product Substance and the other is the source of an action directed to the Product Substance (see Fig 1). As tool, the wrench tightens the bolt via a mechanical field. As instrument, the torque wrench measures the bolt tightening.

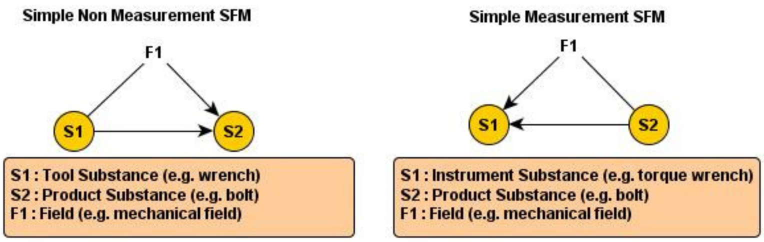

Fig. 1. Graphical representations of Tool & Instrument Substances in SFM

4. Proposal of a SFA formalization

At the end the formalization work, we provide a formal framework for our results using DL and FOL.

4.1. Towards a consistent SFA terminology

A very expressive DL was used for the SFA terminology (SHIQ [6]) and it authorizes a fine representation of SFA terms and provides a rigorous semantic interpretation. For instance, DL definitions of an element and a SFM are given below:

(1) $Element \equiv \forall has\_dynamism.Dynanism \cap \forall has\_rythm.Rythm \cap \forall has\_structure.Structure$
(2) $SubstanceFieldModel \equiv TRIZModel \cap \exists has\_element.Element$

To avoid burdening the reading of this paper by describing the entire SFA terminology obtained in DL, we propose to give a summary report of the DL definitions (see Table 1) translated into informal language. This report presents the most SFA useful terms and our definition proposal.

Term	Definition
Substance-Field Model	Representation of a material system composed at least of one element.
Element	Substance or field, it represents the basic entities of the material world. It has as attributes dynamism, rhythm and structure.
Field	Immaterial entity present in a defined space exerting some force at any point in this space. It is characterized by its intensity.
Substance	Material entity, it may be organic and inorganic, natural or artificial. The substance can be represented as a SFM.
Simple SFM	Combination of exactly of two substances and a field which generates an interaction between the substances. It represents a minimal technical system.
Interaction	Connection between two substances, it is the field sensitive expression. It could be qualified as useful, harmful, excessive, or insufficient.
Action	Particular case of interaction. It is a directed connection, as an Euclidean vector, it connects an initial substance with a terminal substance.
Product Substance	Substance which does not achieve the function of the system.

Tool Substance	Substance that achieves the function of the system and it is the source of the action that could be interpreted as the function.
Instrument Substance	Substance that achieves the function of the system and it is the target of the action that could be interpreted as the function.
Incomplete SFM	Combination of two elements at the most.
Complete SFM	Combination of at least two substances and a field.
Complex SFM	Combination of at least two substances and two fields.
Chain SFM	Combination of exactly three substances and two fields.
Double SFM	Combination of exactly two substances and two fields.
Developed Simple SFM	Simple SFM with one of its substances decomposed in terms of SFM.
Measurement SFM	Complete SFM with an Instrument Substance.

Table 1. SFA terminology summary report

4.2. Towards a systematic SFA

The formalization of SFA definitional knowledge presented in the previous section 4.1 is a necessary step before the formalization of SFA conditional knowledge. In fact, conditional knowledge is related to the handling of definitional knowledge. During this stage, inventive standards have been translated into FOL rules: *If X then Y* (with *X* and *Y* as predicate symbols)

At the end of this formalization work, 8 sets of FOL rules have been obtained:

1. the SFM Transformation rules set (with *X*, *Y* as SFM),
2. the Substance Addition rules set (with *X*, *Y* as Substance),
3. the Field Addition rules set (with *X*, *Y* as Field),
4. the Segmentation rules set (with *X*, *Y* as segmentation attribute of a Substance),
5. the Porosity rules set (with *X*,*Y* as porosity attribute of a Substance),
6. the Dynamism rules set (with *X*, *Y* as dynamism attribute of an Element),
7. the Structure rules set (with *X*,*Y* as structure attribute of an Element),
8. the Rhythm coordination rules set (with *X*,*Y* as rhythm attribute of an Element).

The SFM Transformation rules consider only the information from the 76 Standards which are related to the SFM. We have extracted from the 76 standards all the Generic Problematic SFM and all the Generic Solution SFM. Generic Problematic SFM are used as premise (*X*) of the rules. Generic Solution SFM are used as conclusion (*Y*). Different standards could be represented by a SFM transformation rule. For example, let's consider the following rule with *p* a problematic situation and *s* its possible solution:

If SimpleSFM(p) $\cap \neg$ *(majorModificationOf(p)) then DevelopedSimpleSFM(s)*

Seven inventive standards can be represented by this rule (standards 1.1.2., 1.2.1., 1.2.2., 2.1.1., 2.4.5., 4.4.2., and 4.4.3). Even if SFM transformations rules are more general, we manage to reproduce most of inventive standards by coupling then with other rules sets. The Substance Addition rules and the Field Addition rules are recursively used with the SFM Transformation rules, the general processes induce by those rules are respectively synthetized by the flow charts in Fig 2 and Fig 3.

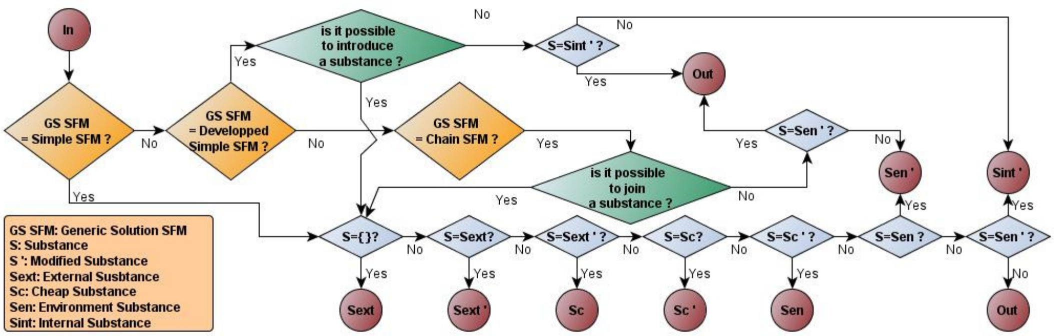

Fig. 2. Flow chart of the process implied by Substance Addition rules

The Substance Addition rules mainly come from the inventive standards sub class 5.1. They enable to introduce or replace the substance needed by a Generic Solution SFM. In Fig 2, four types of substances and their respective modifications are proposed. The Substance Addition rules induce an order for substance introduction testing according the Generic Solution SFM. In the case of Simple SFM, if no trial has been performed then some external substances have to be tested. If external substances do not resolve the problem, modified external substances have to be tested and so on.

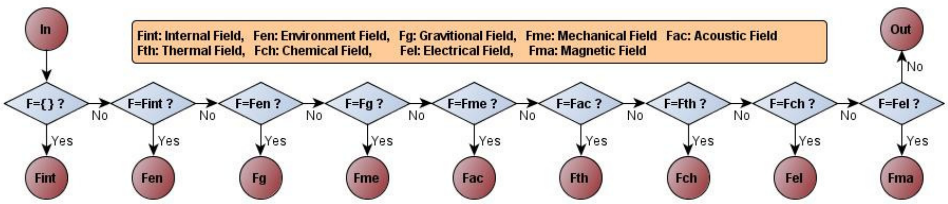

Fig. 3. Flow chart of the process implied by the Field Addition rules

Field Addition rules set implies a field testing sorted process too (see Fig 3). However we can notice a difference. Substance Addition rules imply to successively try some substances from the outer to the inner of the SFM when Field Addition rules propose the opposite process.

As Element Addition rules, the SFM Transformation rules involve a systematic SFM transformation process. This systematic process leads to consider three sub processes as shown in Fig 4. If a Problematic SFM is not a Complete SFM then the SFM Synthesis process is applied. In the opposite case, if no major modification of the actual problematic SFM is envisaged then the SFM Improvement process had be followed else the SFM Evolution process must be applied.

Fig. 4. Flow chart of general process implied by the SFM Transformation rules

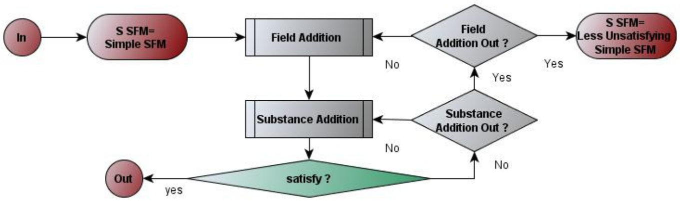

Fig. 5. Flow chart of SFM Synthesis process

The SFM Synthesis process (Fig 5) proposes to build a Simple SFM by trying first (if it is necessary) to introduce a new field according to the Field Addition rules (Fig 3). Then (if it is necessary) a substance could be added by following the Substance Addition rules (Fig 4). The Simple SFM thus created had to be interpreted as satisfying or not. If not, the Substance Addition rules continue until the SFM is suitable. If no substance is interesting then the next field (proposed by the Field Addition rules) is tested and the Substance Addition rules are applied all over again. At the end of all iterations, if no satisfying Simple SFM is found the less unsatisfying one must be conserved. It will be used as input for the SFM Improvement (Fig. 6) or Evolution processes (Fig. 7).

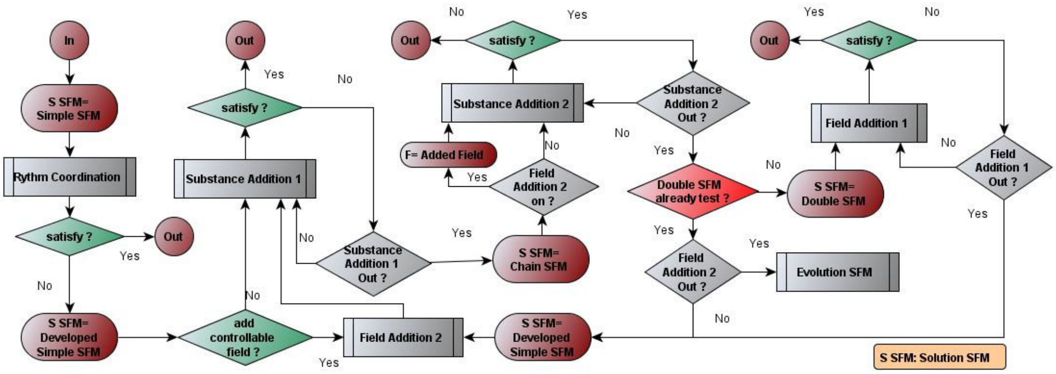

Fig. 6. Flow chart of SFM Improvement process

The SFM Improvement process is represented in Fig. 6. It corresponds to the inventive standards 1.1.2 to 1.2.5, the sub class 2.1 and the standards 2.4.5 and 2.4.6. It starts by the Rhythm coordination rules. If this first rules set is not successful, the Developed Simple SFM is considered as a Solution SFM and two options are proposed. The Developed Simple SFM is specified by either a new substance or a new field and a new substance. If no satisfying solution are found after all Substance Addition process 1 iterations, Chain SFM must be tested as Solution SFM and specified by applying the Substance Addition process 2. If no result occurs, the Double SFM must be tested as well in combination with the Field Addition process 1. When all fields have been unsuccessfully tested to realize the Double SFM, the Developed Simple SFM is again considered as a Solution SFM. It is instantiated with a field proposed by the Field Addition process 2 and the Substance Addition process 1 is again applied. If no satisfying solution is thus found, the same operation has to be realized with some Chain SFM. The process alternates between the Developed Simple SFM and the Chain SFM by incrementing the Field Addition process 2 until a solution proposal is approved or until the SFM Evolution process is launched.

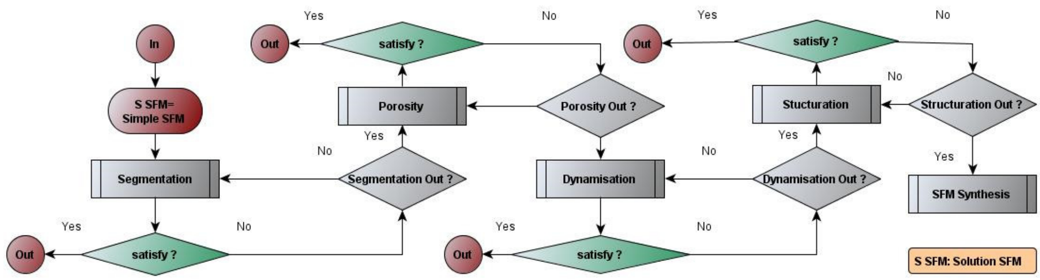

Fig. 7. Flow chart of SFM Evolution process

The SFM Evolution process implies some important modifications (Fig.7). It reproduces the underlined transformations in the standards from 2.2.2 to 2.2.6, in the sub class 2.3 and in the standards from 2.4.8 to 2.4.10. As shown in Fig. 7, it leads to successively apply the Segmentation rules, the Porosity rules, the Dynamism rules and the Structure rules.

The Segmentation rules propose to segment substances with a particular order (non-segmented, macro-segmented, micro-segmented, gel, liquid, aerosol, gas). The Porosity rules imply different degrees of porosity for substances (no cavity, one cavity, macro cavities, micro-cavities, structured micro- cavities). The Dynamism rules lead to change field and substance dynamism level. Field could change from a permanent field to a pulsed one. Substance could be exchanged by one with a joint, many joints or by a flexible one. The Structuration Rules lead to change the element structure (field or substance structure).

4.3. The systematic SFA on an example

To illustrate our systematic SFA, we propose to apply it on a problem of leakage detection in a refrigerating system. The corresponding problematic SFM is a Simple SFM (Fig. 8) with S1, the refrigerating system leak, S2, the human eye and an insufficient action from S1 to S2 via an optical field. Our SFA begins with the flow chart in Fig. 4. The SFM Synthesis process could not be used because of the Simple SFM. We have the choice between two processes: SFM Improvement or the SFM Evolution.

The SFM Improvement process is retained (Fig. 6). It considers the Simple SFM as first Solution SFM and it suggests coordinating it (Fig. 8, S.SFM 1). Then if it's doesn't work, a Developed Simple SFM has to be considered. We decide not to add any field and we directly apply the Substance Addition process 1. Considering our current Solution SFM and the prohibition of substance introduction, the Substance Addition process (Fig. 2) suggests adding a modified internal substance (Fig. 8, S.SFM 2). If the problem is not resolved, the SFM Improvement process proposes to try next a Chain SFM (Fig. 6). As the Field Addition process 2 is not currently going on, we jump directly to the Substance Addition process 2 to instantiate the Chain SFM with some substances. The Substance Addition process 2 leads to investigate successively the interest of different substances. If these Chain SFM (Fig. 8, S.SFM 3-9) are not satisfying, then a Double SFM has to be instantiated via the Field Addition process 1. The different fields have to be tested one by one (Fig. 3). If no Double SFM (Fig. 8, S.SFM 10-18) are satisfying, then the Developed Simple SFM has to be reconsidered but instantiated with the Field Addition process 2 and the Substance Addition process 1. It leads to add in the current Solution SFM an internal field and a modified internal substance (Fig. 8, S.SFM 19). If it is still not suitable, then we have to retry some Chain SFM instantiated by an internal field and the substances induced by the Substance Addition process 2. If no one of those SFM proposals (Fig. 8, S.SFM 20-26) corresponds to a solution, it proposes to try the next field induced by the Field Addition process 2 (the environmental one) and so on.

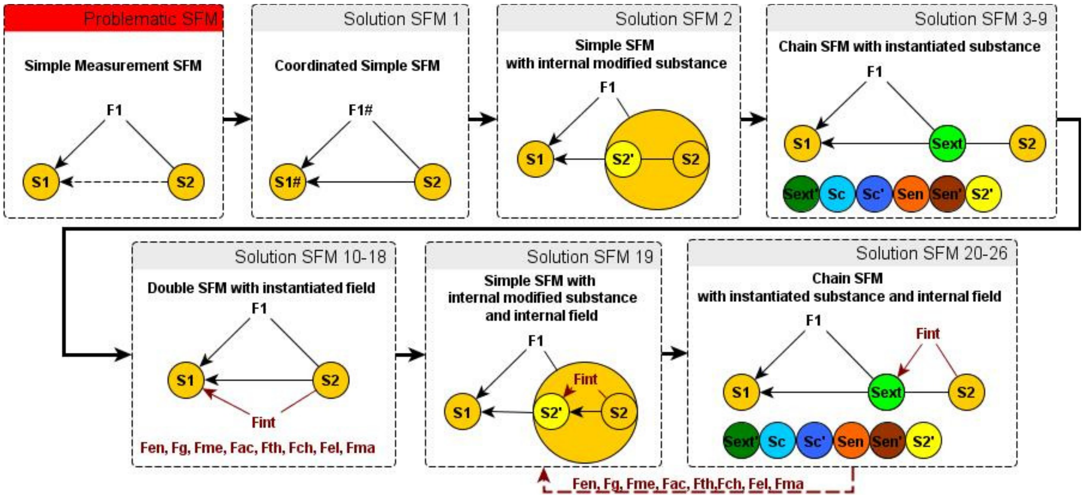

Fig. 8. Overview of the solution SFM induced by the systematic SFA on the leakage detection problem

5. Conclusion

Our SFA formalization reproduces faithfully the traditional SFA almost entirely. Only the standards class 3 is not reproduced. This class refers to some systemic transformations. For example, one of its standards suggests passing from a single technical system to poly technical system. This class does not consider any SFM in terms of substances and fields. From our perspective, it should be removed from the inventive standards. A previous formalization sketch realized in [8] shares this conclusion, and suggests putting it in another TRIZ knowledge base as the evolution trends.

However, except for class 3, all traditional standards are reproduced with the 8 rules sets. Even if the interaction attribute is absent from the 8 rules sets, it has no impact on their validity. We considered as trivial the fact that if there is a problematic interaction (harmful, insufficient, excessive) in a Problematic SFM, the modification implied by a standard aims to counteract it. For example, if a Problematic SFM has an insufficient interaction and if the combination of the 8 sets implies to add a substance, then according to us it trivially implies that this substance must enhance this interaction.

The standards of the class 4 are redundant. According to us it is a synthesis of the class 1 and 2 applied to measurement systems. The definition that we propose as a specific case of a Complete SFM prevents us from this redundancy without forgetting them.

As explained in the beginning of this paper, this work is a part of a project that aims to implement a TRIZ knowledge base system. This SFA formalization is the first brick of a larger operational ontology of the SFA that could be found in [20]. The operational ontology is implemented in a hybrid system combining FOL and DL, CISNA [21]. It includes a physical effect knowledge base and it capitalizes the previous SFA in a study case knowledge base. Both knowledge bases help to interpret the Solution SFM by analogical reasoning. As in [22], we believe that it will facilitate the innovative design in industry though a better SFA understanding and practicing.

References

[1] Cavallucci, D., Rousselot, F., *Evolution hypothesis as a means for linking system parameters and laws of engineering system evolution*, 2011, Procedia Engineering 9 , pp. 484-499.

[2] Zanni-Merk, C., Rousselot, F., Cavallucci, D., *An Ontological Basis for Inventive Design*, 2009, Computers in Industry, Vol. 60, Num. 8, p. 563-574.

[3] Rousselot F, Zanni C, Cavallucci D., *Towards a Formal Definition of Contradiction in Inventive Design*, 2012, Computers in Industry, vol. 63, p. 231-242.

[4] Cavallucci, D., Lutz, P., Kucheavary, D., *Converging in problem formulation: a different path in design*, 2002, Proceedings of the design engineering technical conferences & computer and information in engineering Conference, September, Montreal.

[5] Czerepenski, R. *Through the eyes of an american TRIZ specialist*, 2003, Triz Journal, May.

[6] Baader, F., Calvanese, D., McGuinness, D., Nardi, D., Patel-Schneider, P.F., *The Description Logic Handbook: Theory, Implementation and Applications*, 2003, Cambridge University Press.

[7] Savransky, S.D., *Engineering of creativity : An introduction to TRIZ methodology of Inventive problem solving*, 1998, CRC, ISBN 0-8493-2255-3.

[8] Soderline, P., *Thoughts on S-Field Models and 76 standards-Do we need all the Standards ?,*2003, Triz Journal, May.

[9] Soderline, P., *Thoughts on Fields, Is the concept of field indisputable ?*, 2003, Triz Journal, July.

[10] Mao, X., Zhang, X., Abourizk, S., *Generalized solutions for Su-Field Analysis*, 2007,Triz Journal, August.

[11] Altshuller, G.S., *Creativity as an exact science,* 1984, CRC(ed), ISBN-10:0677212305.

[12] Salamatov,Y.*, Triz : The right solution at the right time,* 1999, Insytec Inc (ed.), ISBN9080468010.

[13] Uschold, M., King, M., *Towards a methodology for building ontologies*, 1995, Proceedings of the workshop on basic ontological issues in knowledge sharing, IJCAI'95.

[14] Szulman, S., Biébow, B., Aussenac-Gilles, N., *Structuration de terminologies à l'aide d'outils d'analyse de textes avec TERMINAE*, 2002, TAL: Hermès, Paris, Vol. 43, n°1, p103-128.

[15] Terninko, J., Domb, E., Miller, J., *The seventy-six Standard Solutions, with Examples-Class 1-2-3-4-5*, 2000, TRIZ journal, February-July.

[16] Schmid, H.*, Improvements in Part-of-Speech Tagging with an application to german,* 1999, Natural Language processing Using very large Corpora, Kluwer Academic Publishers, ISBN : 0792360559, p13-25.

[17] Aubin, S. & Hammon, T., *Improving Term extraction with terminological resources*, 2006, In advances in natural Language Processing, Salakoski, T., Ginter, F., Pyysalo, S. & Pahikkala (Eds), Aôut, p 380-387, LNAI 4139.

[18] Franconi, E. & Gary, N., *The ICOM Tool for Intelligent Conceptual Modelling*, 2000, In proceedings of 7 th International workshop on knowledge representation meets databases (KRDB'00), Berlin, Germany, August.

[19] Simondon, G., *Du mode d'existence des objets techniques*, 2001, Aubier (ed.), ISBN 2-7007-34149, Paris.

[20] Bultey, A., De Beuvron, F., Rousselot, F., *A substance-field ontology to support the TRIZ thinking approach*, 2007, IJCAT 01/2007; 30:113-124. pp.113-124.

[21] Bultey, A., Zanni, C., Rousselot, F., De Beuvron, F., *A Hybrid System Combining Description Logics and Rules for Inventive Design*, 2009, Knowledge-Based and Intelligent Information and Engineering Systems, Santiago, September 28-30.

[22] Cavallucci, D., *A research agenda for computing developments associated with innovation pipelines*, 2011, Computers in Industry 62 (4), pp. 377-383.